AN INVESTIGATION OF POSSIBLE DIFFERENCES IN GROWTH, FORM AND VOLUME OF YOUNG-GROWTH SOUTHWESTERN PONDEROSA PINE ON TWO DIFFERENT HABITAT TYPES

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FINAL REPORT

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Rocky Mountain Forest and Range Experiment Station
and
School of Forestry, Northern Arizona University

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INTRODUCTION

One of the reasons for the development of habitat type classifications was to provide a stratification for management information which would make management information more accurate and make research information more easily applicable to managed sites.

Pfister _et al._ (1977) showed differences in height of ponderosa pine (_Pinus ponderosa_ Laws.) between habitat types in the ponderosa pine series. Their data also showed differences in yield capability, but no differences in basal area or site index. Data in the ponderosa pine classification by Hanks, Fitzhugh, and Hanks[1] showed possible differences in site indices between at least two habitat types within the ponderosa pine series in Arizona.

It is generally accepted that the growth form of ponderosa pine varies according to competition, at least on more open sites. Basal areas of ponderosa pine sites sampled by Hanks _et al._ show clear differences between habitat types. Their data (unpublished) were not collected with a sampling scheme designed to be unbiased for basal area and site index, but whatever bias did exist is unlikely to account fully for the magnitude of the differences their data showed.

The average basal area of five phases of the ponderosa pine/blue grama habitat type, with a total sample size of 63 trees, was 54 square feet. The average of both phases of the ponderosa pine/screwleaf muhly habitat type, with a sample size of 43 trees, was 90 square feet. The average number of trees per acre for the same types was 78 and 122 respectively. Both basal area and number of trees, therefore, indicated differences between habitat

[1] Final Report to Regional Forester, USDA, Forest Service, Albuquerque, NM, February 28, 1977, v + 143 pp.

types due to competition. Higher site indices were found in habitat types having more crowding.

OBJECTIVES

The objectives of this study were to examine two habitat types which had a potential for different tree form, and to determine if the magnitude of growth, form, and individual tree volume differences were of practical importance.

STUDY AREA

Twenty young-growth ponderosa pine were selected on each of two habitat types to be sampled for various measurement parameters. The types were inspected by Dr. Frank Ronco, Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona, prior to measurement and chosen for their dissimilarity.

Cinder Hills

The twenty trees measured in the Cinder Hills area are located in the SE¼, Section 34, Township 23 North, Range 8 East, G&SRB&M, on a narrow strip east of and adjacent to Forest Service Road 776, and approximately two miles south of Sunset Crater National Monument. Ages ranged from 38 to 78 years ($\bar{x}$ = 49.20), and total heights were from 37 to 54 feet ($\bar{x}$ = 44.00). Twelve dominants and eight codominants were measured.

The habitat type is described as ponderosa pine/screwleaf muhly-sand bluestem phase; the soil is Sizer-Rudd-Bandera association, "shallow to deep, gravelly or cindery loamy soils on cinders, 0 to 45 percent slopes" (Soil Conservation Service, 1972).

Rattlesnake Burn

Trees sampled on Rattlesnake Burn are within a ponderosa pine/screwleaf

muhly-gambel oak phase in the SE¼, Section 20, Township 19 North, Range 5 East, G&SRB&M, west of and near the intersection of Forest Service Roads 538A and 539. Soils are designated as the Soldier-Hogg association, "moderately deep and deep, gravelly or cobbly loamy to clayey soils on limestone and calcareous sandstone, 2 to 30 percent slopes" (Soil Conservation Service, 1972).

Ages ranged from 53 to 70 years ($\bar{x}$ = 63.25), and heights from 56 to 70 feet ($\bar{x}$ = 63.45). Fourteen dominants and six codominants were sampled.

PROCEDURES

Twenty well-formed, non-defective dominant and codominant trees without evidence of prior suppression were selected for measurement on each habitat type. An attempt was made to select four trees in each of the one-inch diameter classes between nine and thirteen inches.

DBH was measured to the nearest 0.1 inch with a diameter tape; in addition, DBH and stump diameters were measured with a calipers to the nearest 0.1 inch to coincide with the line of sight (LOS) upper stem diameter and length observations taken with a Barr and Stroud Type FP-15 optical dendrometer. Total height was determined to the nearest foot with a clinometer, and compared in the office with the optical dendrometer total height measurement.

Four evenly distributed diameter and segment length readings were taken on the upper stem with the optical dendrometer; diameter was also recorded at 17.5 feet (designated on a leveling rod and taken with the optical dendrometer) for form class determination.

Breast high age of each tree was measured by means of a core taken perpendicularly to the LOS, and radial increment was determined from the core for the previous ten- and twenty-year intervals.

Summary measurement and mensurational data for the sample trees on the two habitat types are listed in Appendix A. Appendix B presents the numerical values of the statistical comparisons described in COMPARATIVE ANALYSES.

COMPARATIVE ANALYSES

Site Index. Site indices of nine suitable candidates from each area were determined from breast high age and total height (Minor, 1964). A Student's t-test (1)[2] indicated a highly significant difference in site indices between the two types. The mean site index was 80.17 at Cinder Hills and 92.94 at Rattlesnake Burn. There was a much greater range in site indices at Cinder Hills (65.9 to 97.4) than at Rattlesnake Burn (89.5 to 98.8).

Tree number one at Cinder Hills (Appendix A), with a site index of 97.4, was an apparent outlier and not representative of other site values on the habitat type, although age and height measurements were re-checked and all criteria for a suitable site tree candidate were met. This tree emphasizes the wide variation in individual site indices at Cinder Hills. When the value for this tree is eliminated, the average site index at Cinder Hills is lowered to 78.01.

Form Class. Form class was determined by

$$\frac{\text{d.i.b.}_{(17.5\text{ ft.})}}{\text{D.B.H.o.b.}} \times 100$$

Diameter inside bark at 17.5 feet (16.5 foot log + 0.5 foot stump + 0.5 foot trim) was estimated by

$$0.838(\text{D.O.B.}) + 0.135 \quad \text{(Voorhies } \underline{\text{et al.}}\text{, 1974)},$$

2 Numbers in parentheses refer to the specific comparative statistical data in APPENDIX B.

and a comparison of form class differences on the two areas was made using Student's t-test (2).

There was a highly significant difference in form class between the two areas. Again, Cinder Hills had the widest variation (52 to 84, $\bar{x} = 65.35$), compared to a range of 66 to 79 ($\bar{x} = 73.15$) at Rattlesnake Burn.

<u>Growth.</u> Differences in ten- and twenty-year basal area growth patterns on the two habitat types were examined by group regression analysis (Freese, 1967). The independent variable was the calculated individual tree basal area ten or twenty years prior to the measurement year; present basal area was the dependent variable.

No significant differences in either the slopes or the levels of the linear regressions for the two areas based on ten- and twenty-year growth patterns for the two areas were noted, indicating that a common regression could be used as a basal area growth predictor at both locations (3,4).

Although there was no significant difference in the regression, the Rattlesnake burn r^2 values were higher in both the ten (.978) and twenty (.936) year regressions than Cinder Hills (.810 and .870 respectively), indicating a higher explanation of the variation in y associated with x, and suggesting a more predictable uniformity in the growth rate on the Rattlesnake Burn.

<u>Individual Tree Volumes.</u> Total gross cubic foot volume inside bark was determined for each tree using Smalian's formula

$$\frac{BA_l + BA_u}{2} \text{ X Length}$$

Segments cumulated in the total were

1. Ground level to stump (0.5 foot, using stump caliper-determined diameter and treated as a cylinder.

2. Stump to DBH (4.0 feet, using DBH caliper-determined measurement).

3. DBH to first upper stem diameter obtained with the optical dendrometer, varying segment length.

4. Continue with optical dendrometer upper stem diameters and lengths (four per tree).

Inside bark diameters were determined by Voorhies' (1974) equation for young-growth Southwestern ponderosa pine bark thickness.

The total gross cubic foot volume for each tree was also obtained using Hann and Bare's (1978) unforked tree total stem gross cubic foot volume (V_t) for blackjack pine on the Coconino, Tonto, and Lincoln National Forests, where

$$V_t = .0810724804 + .00198351037D^2H$$

Linear regressions were calculated for the optical dendrometer volumes and for Hann and Bare's volumes for both Rattlesnake Burn and Cinder Hills using D^2H as the independent variable. Group regression analyses were conducted on the results.

There was no significance in slope or level of the regression lines based on optical dendrometer total cubic foot volumes for Cinder Hills and Rattlesnake Burn (5). Differences were also non-significant in an examination of the slopes and levels of the Cinder Hills regressions derived by optical dendrometer measurements and by Hann and Bare's volume equation (6).

For the two equivalent Rattlesnake Burn regressions (optical dendrometer volumes vs Hann and Bare's volumes) there was no difference in slope, but a highly significant difference in the level of the lines was indicated (7). The difference between the calculated F (8.2258) and the tabular ($F_{1,37} = 7.37$) is relatively small, and possibly reflects a minor actual difference, a small sample from high productivity sites in the D^2H range of Hann and Bare's data, or an anomaly inherent in the bark thickness

equation used to convert the upper-stem diameters to inside bark measurements.

When the regressions for the optical dendrometer volumes from Rattlesnake Burn and Cinder Hills were combined and compared with Hann and Bare's combined regression from the two areas, there was no significant difference in the slope or level of the lines (8), suggesting that Hann and Bare's volume equation has practical applicability over a range of divergent sites, tree forms, and habitat types.

CONCLUSIONS

This study indicates that regionally accepted diameter and height vol- equations for young-growth Southwestern ponderosa pine (Hann and Bare, 1978) are adequate predictors of individual tree volumes, and that differing stand site indices and individual tree form have little effect on reliable estimations.

A corollary observation in this study was the wider intra-habitat type variation and lessened predictability in form, site, and growth on the less productive and harsher habitat type at Cinder Hills. Whether this is a phenomenon common to trees on poorer habitat types, or whether it occurred at Cinder Hills because varying depth of the cinders has a pronounced effect on individual tree survival and growth is unknown.

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APPENDIX A

CINDER HILLS

Sample Tree Measurement and Mensurational Data

Tree Number	DBH (in.)	Height (ft.)	Age	Crown Class	Form Class	Site Index	Optical Dendrometer Total Cubic Feet	Hann and Bare Total Cubic Feet
1	12.1	51	44	1	69	97.4	14.06	14.89
2	9.1	41	38	2	68		6.33	6.82
3	12.1	48	51	1	66	79.4	14.48	14.02
4	9.7	37	37	2	70		8.04	6.09
5	10.4	38	39	2	59		8.04	8.23
6	10.1	47	46	2	61		8.40	9.59
7	10.3	37	46	2	52		7.66	7.87
8	9.3	35	56	2	67		7.49	6.09
9	14.1	51	60	1	70	73.8	21.13	20.19
10	13.2	54	55	1	65	84.4	15.67	18.74
11	12.2	47	55	1	84	72.6	15.85	13.96
12	10.5	42	41	1	66		9.71	9.27
13	13.3	51	51	1	69	84.8	17.69	17.98
14	12.5	46	52	1	68		14.47	14.34
15	9.6	35	42	2	60		6.65	6.48
16	11.6	41	50	2	63		9.99	11.02
17	11.4	42	43	1	59	80.2	9.00	10.91
18	12.1	43	55	1	61	65.9	11.79	12.57
19	11.3	45	45	1	62	83.0	10.79	11.48
20	13.2	49	78	1	68		16.83	17.02
$\bar{x}$	11.5	44.0	49.2		65.4	80.17	11.70	11.92
s		6.6	9.5		6.4	8.99		
CV%		15.1	19.3		9.8	11.21		
n	20	20	20		20	9	20	20

RATTLESNAKE BURN

Sample Tree Measurement and Mensurational Data

Tree Number	DBH (in.)	Height (ft.)	Age	Crown Class	Form Class	Site Index	Optical Dendrometer Total Cubic Feet	Hann and Bare Total Cubic Feet
1	10.2	56	61	1	74		12.86	11.64
2	10.1	62	61	1	67	89.5	11.63	12.63
3	10.8	57	70	2	69		12.95	13.27
4	10.7	69	70	1	73	89.5	15.32	15.75
5	13.1	68	68	1	72	90.2	24.93	23.23
6	12.9	63	71	1	75		22.23	23.19
7	11.7	59	61	2	66		16.21	16.10
8	9.7	69	60	1	77		14.58	12.96
9	9.9	58	67	1	73		13.09	11.36
10	13.7	69	64	1	74	96.2	26.61	25.77
11	12.8	57	63	1	75		20.15	18.60
12	12.6	65	60	1	73	95.4	20.33	20.55
13	9.1	61	61	2	79		12.06	10.10
14	10.6	69	62	1	77	98.8	16.22	15.46
15	12.8	70	65	1	72	96.4	23.16	22.83
16	11.8	62	60	1	70	90.7	17.75	17.20
17	12.1	63	62	1	72	89.8	18.23	18.38
18	9.2	58	62	2	72		10.81	9.82
19	11.2	65	53	2	70		14.90	16.25
20	11.8	69	64	2	77		21.40	19.14
$\bar{x}$	11.4	63.5	63.3		73.2	92.9	17.27	16.60
s		4.9	4.3		3.6	3.7		
CV%		7.7	6.8		4.9	4.0		
n	20	20	20		20	9	20	20

APPENDIX B

STATISTICAL COMPARISON DATA

(1) SITE INDEX - Cinder Hills vs Rattlesnake Burn
Student's t-test (unpaired)

df	Calculated t value	Tabular t value (.05)	Tabular t value (.01)
16	3.96	2.57*	2.92**

(2) FORM CLASS - Cinder Hills vs Rattlesnake Burn
Student's t-test (unpaired)

df	Calculated t value	Tabular t value (.05)	Tabular t value (.01)
38	4.75	2.02*	2.75**

(3) GROWTH (Ten year) - Cinder Hills vs Rattlesnake Burn
Group regression analysis

	a	b	r^2
Cinder Hills	.103108	1.083802	.810
Rattlesnake Burn	.093667	1.089765	.978

	df	Calculated F value	Tabular F value (.05)	Tabular F value (.01)
Slope	1,36	.00185	4.11^{NS}	7.39^{NS}
Level	1,37	.09069	4.10^{NS}	7.37^{NS}

(4) GROWTH (Twenty year)- Cinder Hills vs Rattlesnake Burn
Group regression analysis

	a	b	r^2
Cinder Hills	.279247	1.127721	.870
Rattlesnake Burn	.179722	1.216795	.936

	df	Calculated F value	Tabular F value (.05)	Tabular F value (.01)
Slope	1,36	.47273	4.11^{NS}	7.39^{NS}
Level	1,37	.31493	4.10^{NS}	7.37^{NS}

STATISTICAL COMPARISON DATA

(5) OPTICAL DENDROMETER TOTAL CUBIC FOOT VOLUME - Cinder Hills vs Rattlesnake Burn
Group regression analysis

	a	b	r^2
Cinder Hills	.049644	.001877	.931
Rattlesnake Burn	.783478	.001980	.952

	df	Calculated F value	Tabular F value (.05)	Tabular F value (.01)
Slope	1,36	.41883	4.11^{NS}	7.39^{NS}
Level	1,37	6.71059	4.10^{NS}	7.37^{NS}

(6) CINDER HILLS - Optical dendrometer total cubic foot volume vs Hann and Bare's total cubic foot volume
Group regression analysis

	a	b	r^2
Optical Dendrometer	.049644	.001877	.931
Hann and Bare	.084549	.001983	1.000

	df	Calculated F value	Tabular F value (.05)	Tabular F value (.01)
Slope	1,36	.77390	4.11^{NS}	7.39^{NS}
Level	1,37	.72747	4.10^{NS}	7.37^{NS}

(7) RATTLESNAKE BURN - Optical dendrometer total cubic foot volume vs Hann and Bare's total cubic foot volume
Group regression analysis

	a	b	r^2
Optical Dendrometer	.783478	.001980	.952
Hann and Bare	.082471	.001983	1.000

	df	Calculated F value	Tabular F value (.05)	Tabular F value (.01)
Slope	1,36	.00088	4.11^{NS}	7.39^{NS}
Level	1,37	8.22580	4.10^{*}	7.37^{**}

STATISTICAL COMPARISON DATA

(8) CINDER HILLS AND RATTLESNAKE BURN - Optical dendrometer total cubic foot volume combined vs Hann and Bare's total cubic foot volume combined

Group regression analysis

	a	b	r^2
Optical Dendrometer	-.008150	.002028	.951
Hann and Bare	.083588	.001983	1.000

	df	Calculated F value	Tabular F value (.05)	Tabular F value (.01)
Slope	1,76	.360235	3.96^{NS}	6.96^{NS}
Level	1,77	1.520896	3.96^{NS}	6.96^{NS}